Art. XXII.—*On the Country between Melbourne and the Dandenong Creek.*

By T. S. HART, M.A., B.C.E., F.G.S.

[Read 14th November, 1912.]

The area whose features are now dealt with extends from the Yarra, near Toorak and Hawthorn, south-easterly to the Dandenong Creek. A part of it is included in quarter sheets Nos. I. S.E. and I. N.E. of the Geological Survey of Victoria. The Lands Department contour maps of Melbourne and suburbs extend to beyond Box Hill and Oakleigh, and further contour maps of the same department cover the parish of Moorabbin, and the country south of the Gippsland railway as far as Dandenong. Mr. Saxton kindly directed my attention to the latter map, and also furnished me with levels of several other points.

In 1910, Mr. J. T. Jutson[1] in "A Contribution to the Physiography of the Yarra and Dandenong Creek Basins," dealt with a part of this district, but not so much with the southern part. His conclusions, so far as relevant to the present subject, may be summarised as follows:—

The general slope of the country from about Surrey Hills and Mitcham is south-westerly. The name of the Mitcham Axis is given to a line of high land through these two places turning north-east from Mitcham.

Main Creek, and another further west, follow down the general slope to Gardiner's Creek. Gardiner's Creek flows from lower country about Murrumbeena through higher country north of Malvern.

He considers that Main Creek may have originally continued south-west, and that Gardiner's Creek has cut rapidly back and captured the upper part of the original Main Creek.

He admits difficulties in the north-westerly courses of Scotchman's Creek and the Elsternwick Creek. Alternatively he suggests that Gardiner's Creek and its tributaries may be antecedent streams.

1 Proc. Roy. Soc. Victoria, vol. xxiii. (New Series), pp. 469-514.

He suggests also that the "Croydon Senkungsfeld" includes the Carrum Swamp, and possibly part of Port Phillip, and that the west boundary fault of this sunk area is replaced by a gentle tilting about Scoresby and Springvale.

I propose to show that a north-westerly course of the valleys and ridges is the rule south of Gardiner's Creek, and that a north-west and south-east trend of the surface features extends as far as Dandenong, with great regularity in Brighton and Moorabbin, but affected by the southward fall to the Carrum Swamp in the more easterly parts. An important axis extends from Mitcham to the vicinity of Cheltenham and Blackrock, on the line of the continuation of the north-east end of Jutson's Mitcham axis. Another important divide extends from South Yarra to Dandenong, and no outlet can have existed for Main Creek to the south-west. At Murrumbeena, on the contrary, there is a recent diversion of waters north into Gardiner's Creek. The numerous closed and ill-drained hollows and some other points will also be referred to.

General Description of the Area.

A part of this district drains to the Yarra, either direct or by way of Gardiner's Creek. South of this the outlet is direct to Port Phillip by the Elsternwick Creek, and a series of parallel valleys through Brighton and Sandringham. Between Cheltenham and Dandenong the waters run naturally to the Carrum Swamp. With the assistance of shallow drains, waters from near Oakleigh are discharged through this area. The Springvale valley runs south-east, and turns south near Dandenong. It receives tributaries from the north from a little beyond the Fern Tree Gully-road. A small area about Glen Waverley discharges into Scotchman's Creek, ahead of Gardiner's Creek. From Wheeler's Hill to Mitcham a triangular area falls direct to the Dandenong Creek.

The chief dividing line extends from Mitcham south-westerly through Notting Hill to Cheltenham. Parallel to this is the highland from north of Surrey Hills to Malvern, broken by the outlet of Gardiner's Creek. Transverse to these is the divide from South Yarra to near Dandenong, on the south-west side of the valleys of Gardiner's Creek, and the Springvale Creek. The south-west limit of the Elsternwick Creek is a parallel line, as are also the divides between the Brighton valleys. The high land from Wheeler's Hill north-westerly is parallel to these, and in the same line is the Reservoir Hill at Surrey Hills, and the south limit of the Koonung Creek further to the north-west. South-east from

Wheeler's Hill are the Police Paddock Hills, and the Dandenong Creek contracts its valley to pass between these and Wheeler's Hill, as well as changing to a south-easterly direction. The simplicity of such a rectangular plan is broken by the way in which the Gardiner's Creek catchment is enlarged at the expense of its neighbours.

Gardiner's Creek.

North-west of the Malvern Camberwell highland, the fall is direct to the Yarra. The valley from near Malvern railway station has a very direct north-west course. The outlet of Gardiner's Creek has also a north-west direction, and a valley no doubt continues under the basalt to join the buried valley of the Yarra. The fall would be steeper than is now seen in Gardiner's Creek. From the junction of Gardiner's Creek and Main Creek the fall is from 85 to 25 above sea level in three miles. A mile and a-half lower, Gardiner's Creek joins the Yarra at 2 feet above sea level; the probable junction of the buried valleys is a mile or a mile and a half further on, and about 60 feet below sea level. Even allowing the buried valley to extend some distance up Gardiner's Creek, the fall will still be greater than the 20 feet to the mile higher up the valley.

The natural continuation of the Gardiner's Creek valley is by Scotchman's Creek through Oakleigh; a little valley can be followed south-east to Notting Hill. But by far the greater part of the area drained by Gardiner's Creek and Scotchman's Creek is to the north of the main line of Gardiner's Creek. The contributions from the south are insignificant in amount, and the most important of these, the little creek at Murrumbeena, will be shown later to be new.

The mouth of Gardiner's Creek must be a quite early feature. Probably the whole system developed soon enough to secure the waters of the area about Blackburn, which might have gone to Koonung Creek, and to capture Black Flat (Glen Waverley) from the eastern valleys. Throughout the Gardiner's Creek area the streams have cut down to the bedrock. A much larger proportion of the rainfall must be immediately discharged than by a system in the absorptive tertiary rocks. The excavating power of the streams is thereby increased, and the higher levels allow deeper dissection than in the country to the south. No undrained areas of the kind common further south occur. Detail of the course of the creeks is influenced by bedrock structures, which no doubt contribute to the numerous small irregularities.

Area draining to Balaclava and Elsternwick.

A short distance south of the Malvern railway station is a swampy area formerly known as Paddy's Swamp. The 140 ft. contour runs round an area about 40 chains by 10, leaving an outlet at the west end, which, however, cannot drain away all the surface water. Thence the valley falls south-west and west to the flat at Balaclava, reaching the sea to the south of the St. Kilda Hill. South-east from Paddy's Swamp is the flat in the Caulfield Racecourse, and again south-east, another area of difficult drainage, to be referred to later.

The trend of the lowest ground of the Elwood Swamp is from south-east to north-west. Up stream the valley can be followed almost straight to its head north of Cheltenham. The south-west limit of the Elsternwick Creek waters is a ridge from near the power house of the Brighton electric tram south-east in an almost straight line. It is close to the Point Nepean-road from North Brighton to Moorabbin station; thence a little east of the road, which has turned a little more southerly. This may conveniently be called the Moorabbin Ridge. The Elsternwick Creek lies close north-east of this ridge, a small parallel valley intervening at North Brighton. The creek then receives practically nothing from the left bank, but on the right or north side it receives two important tributaries; one of these runs south from near the Caulfield Town Hall, and turns west to join the creek near Gardenvale station. The other flows south, near the Mordialloc railway, receiving much water from its east side, including that from the swamp south of Carnegie station. Here the 140 ft. contour almost surrounds a long narrow area stretching for a mile and a quarter south-east to north-west. The outlet is south-west to the Elsternwick Creek tributary, but at a point a long way back from the north-west end of the elongated hollow. At its south-east end it merges in an ordinary valley from the south-east.

A remarkable broken valley line lies north-east of the Elsternwick Creek. One portion of it runs through the entrance to the Brighton Cemetery, and extends south-east for some distance lower. This part and another north-west of it fall into one of the Elsternwick Creek tributaries. On the same line further south-east, a pair of similar valleys falls into the next tributary, and a fifth section, reaching the Elsternwick Creek by another route, occurs further on, east of the Bentleigh station. It is either a valley broken up by three captures, or indicates a marked tendency to produce valleys along one line.

The head of the Elsternwick Creek is in a broad open valley north of Cheltenham. On each side of the valley the 120 ft. contour runs in two nearly parallel lines from south-east to north-west, 20 to 30 chains apart. The 110 ft. contours come in at the two ends of this flat, a mile and a half apart. Most of the flat drains to the Elsternwick Creek, but the south-east end falls to the south-east and the outlet is steeper than the other end.

The Elsternwick Creek and its tributaries nowhere cut down to the bed rock; probably much of the main valley at least is in less permeable beds low in the tertiary series. The average fall over 4½ miles from 110 to 10 ft. above sea level is about 22 ft. to the mile.

A north-westerly trend of the valleys is the rule throughout this area, but the two tributaries from the north bring nearly all the waters down to the south-west side of the system. The more important of these tributaries receives nearly all its water by north-westerly valleys. The levels along the divides on the north-east and south-east of this system range from 190 to 150. The Moorabbin ridge, however, only reaches 150 at its highest point, and the actual head of the Elsternwick Creek is below 120.

The Brighton and Sandringham Valleys.

These are six parallel valleys with a north-westerly direction. The first is very straight and regular, starting east of the Point Nepean-road, not far north of Cheltenham, running close to the Moorabbin Ridge, and entering the sea at the foot of North-road, North Brighton. The second heads close to the railway between Highett and Cheltenham, but after running north-west for a mile and three-quarters, turns south-west into the third valley. Another valley starts within half a mile of the angle, and continues to the sea on the second valley line. The third extends practically straight from the swamps in Cheltenham Park to Middle Brighton. The fourth heads a mile west of Cheltenham, but after running north-west to a point north of Hampton station, turns south-west into the fifth. On the line of the fourth lower down two other little valleys occur. This series is well seen on the Brighton railway, the first just south of (North) Brighton station; the second and third on each side of Middle Brighton. The fourth is here only represented by a very slight hollow. The railway follows the fifth from Brighton Beach to Hampton, and the sixth is seen inside the Beach-road below Sandringham.

Above the apparent head of the fifth valley east of Sandringham station, there is on the same line a long valley with no outlet, terminating in a lagoon east of the golf club house. A flattening of the grade of all these valleys occurs about the line of the Bluff-road, and on the same line occurs the flattest part of the Elsternwick Creek (except its head and swamps at the mouth). The grades of the valleys are shown in the accompanying table in which the letter D indicates that the valley is here diverted south-west, and the letter B that it is blocked with no free outlet.

On the sixth or Sandringham valley the 40 ft. contour is the last above the cliffs.

Elsternwick Creek and Brighton Valleys. Distances in Chains between Successive Contours.

Levels	E. Ck.	Brighton Valleys. 1	2 upper	2 lower	3	4	5 upper	5 lower	6
130 to 120	—	21	1½	—	29	11	—	—	—
120 to 110	—	38	27	—	60	11	18	—	—
110 to 100	39	44	50	—	26	47	16	—	—
100 to 90	28	19	41	4	18	74	B	12	—
90 to 80	44	48½	85D	14	65	4	—	11	—
80 to 70	52	50	—	41	25	18	—	37	—
70 to 60	23	23	—	37	29	32	—	12½	15
60 to 50	25	23½	—	43	40	23	—	12	14
50 to 40	25	35	—	34	19½	27D	—	12½	16
40 to 30	35	32	—	47	29		—	16	—
30 to 20	52	26		12	29		—	13	—
20 to 10	54	38½		14	20	—	—	—	—
10 to sea	90	3	—	3	3	—	—	—	—
Average 100 to 20 10 ft. fall in	35	32	—	29	32	24	—	16	—
Fall in feet per mile	23	25	—	27½	25	33½	—	50	—

The ridges between the valleys show a gradual descent with few irregularities. On a section at right angles to the valley the south-west side is nearly always lower than the north-east. Taking the general level of the ridges the fall is on the whole west, not north-west. All the departures from regularity in these valleys are the few diversions to the south-west and the loss of grade, producing swamps. Numerous ill-drained or undrained areas occur about the heads of the valleys near Cheltenham, and as far west as close to the Red Bluff, Sandringham. These are usually very closely related to, or actually part of, the valleys. The high land at the head of the series reaches 170 at one point at Cheltenham. The heads of the first valley, and less distinctly the second

and fourth, are continuous with valleys on the opposite fall. The tertiary rocks are never cut through, but less permeable beds are probably often reached, and the waters of the permanent lagoons may be taken as representing the level of permanent saturation about 120 ft. above sea level near Cheltenham.

Parish of Mordialloc and adjacent parts of Moorabbin and Dandenong.

At Mordialloc and Mentone, and east of Cheltenham, and thence north-east to near Clayton, the valleys fall to the south-east off the highland at the heads of the Brighton valleys and the Elsternwick Creek. They commonly show a very regular south-easterly direction, but ultimately their waters reach a channel which runs south from near Clayton to the main drain east of Mordialloc. This is, however, for the most part the natural course of the waters. A valley starts on the South-road, a mile and a half east of Moorabbin station, and runs south-east through the Benevolent Asylum grounds. Another parallel to this starts near the Centre-road, east of Bentleigh, and runs south-east into Reedy Swamp. Another valley starts about a mile west of Clayton station near the Centre-road, and after running south-east for a little distance turns south through Heatherton, becoming the main channel. The fall from 160 to 60 feet above sea level extends over two and a half miles, about 40 feet to the mile, and thus considerably steeper than the Brighton valleys.

A south-easterly valley starts between Oakleigh and Clayton, and its waters are also turned south by an artificial channel into this main channel, but a definite south-easterly trend of the valleys is seen to the east of this made drain.

Ill-drained and swampy places are common within this area. From Heatherton the old Dandenong-road continues south-easterly close to the 70 ft. contour, touching 60 in some of the valleys, but never again reaching 80. Three shallow valleys with a southerly trend cross the road, but in the country between this road and the Gippsland railway a south-easterly trend is often seen and just south of the railway a definite south-easterly ridge marks the south-west limit of the Springvale valley.

Near the main channel south of Heatherton, the contours begin to show the effect of recent alluviation as high as the 40 ft. level, but in the neighbourhood of Mordialloc the well-defined south-easterly ridges and valleys can be seen as low as the 10 ft. contour.

Springvale.—A valley runs in a south-easterly direction near the Gippsland railway from a little beyond Clayton to about a mile before Dandenong. It receives very little from the south; on the south side of the railway is the ridge just referred to gradually descending in three miles from 170 to 100 above sea level. This Springvale valley receives tributaries from the north; the most westerly of the tributaries receives valleys falling south-east off the high land about Notting Hill. A fall of 20 feet to the mile in the Springvale valley seems to be sufficient to allow recent scouring out of the channel, necessitating the protection of bridges. This is in agreement with Gardiner's Creek. The Brighton valleys, though slightly steeper on the whole, show little tendency to scour, a difference which is no doubt due to the slow delivery of rain from the highly absorptive tertiary sands. The valleys of Springvale and its tributaries are often comparatively broad and open.

East of Notting Hill one of the heads of this system runs south-south-west across the Fern Tree Gully-road. It starts about three-quarters of a mile to the north-east where a low ridge separates it from Glen Waverley.

Glen Waverley.—This is an open valley with gentle slopes near the crossing of Springvale-road and the Waverley-road. Its west end is highest, being formed of the hills north-west of Wheeler's Hill. Beyond these there is a rapid fall to the Dandenong Creek. The outlet from Glen Waverley is now by a steep narrow valley to Scotchman's Creek. The open valleys could have been formed if this outlet were maintained for some time at a higher level. The present outlet crosses the high land north of Notting Hill, and it is probable that the original outlet was south-easterly across the low ridge which now separates Glen Waverley from the valley falling to Springvale.

Northward from Glen Waverley the Springvale-road crosses a number of gullies which fall east to the Dandenong Creek. A line drawn north-west from Wheeler's Hill and another south-west from Mitcham would mark the approximate limits of this area. Further north, at the corner of Canterbury-road, there is a valley which forms one of the heads of Main Creek. The above description is sufficient to show clearly that the north-west and south-east valleys are the rule throughout the country south of Gardiner's Creek and the Springvale valley. There is no reason to exclude these two creeks from this regular system. North of Gardiner's Creek the south-westerly fall of its principal tributaries is the prominent feature, but this it to some extent anticipated in the tributaries of the Elsternwick Creek. Main Creek receives most of its waters

from the east. That the north-west valleys have not ceased is also shown in the course of the north-east head of Main Creek and of the Koonung Creek.

North of the Springvale Valley the southerly fall is conspicuous, but a north-westerly ridge again appears through Wheeler's Hill.

The Notting Hill Cheltenham Axis.—The importance of this divide is shown in the description. It is not a narrow ridge, but a broad elevation or flat arch in shape, with a gradually decreasing elevation to the south-west. Hence the actual heads of valleys are not, and need not ever have been, on a straight line. The heads are sometimes nearer to one side and sometimes to the other. The general form of the axis is well shown by the 200, 150 and 100 ft. contours. They run in a southerly direction on the west side, cross the axis and run away to the north-east. The fall in levels on the crown of the axis is not, however, uniform. At Mitcham the elevation is about 500; at Notting Hill 320. Thence the fall is somewhat rapid to the Centre-road, where the 200 ft. level is passed, but at Cheltenham the highest point is still 170. This is certainly an isolated summit, but the part of the axis north of Cheltenham has probably suffered more severely, as the valleys are near together, and in some places nearly or quite cross the axis.

The open valley at the head of Elsternwick Creek suggests that perhaps this divide was not original, but that valleys once headed clear of it and ran across its position. But though the eastern fall may have been steepened a little, there is no indication of any general alteration of direction of flow even in those valleys which nearly cross the high land. The head of the Elsternwick Creek alone might have been thought to have once started further east, and to have lost its upper part by a subsidence in this direction, but the valley of Reedy Swamp has certainly always been an easterly valley, and generally the whole series of valleys gives no support to any other view than that this axis is original. The flat at the head of Elsternwick Creek is no doubt due to the great power of widening that a valley in these permeable beds acquires as soon as it reaches an impermeable bottom. The permanent water in brick holes east of Moorabbin station indicates that here at least the permanent water level is practically at the surface (110 ft. above sea level), and the mere existence of the brick pits shows that the bed of the valley is not in the purer and more permeable sands.

The northward part of the axis beyond Notting Hill is indeed broken by the outlet from Glen Waverley, but this is obviously new, not an original feature.

The Coast Line.—Ormond Point (Red Bluff, St. Kilda), lies on the extension of the ridge south-west of the Elsternwick Creek. The coast soon curves and runs nearly south, crossing the Brighton valleys at a small angle. The projecting points are due to the greater resistance of the lower beds of the tertiaries, and do not correspond in position to the ridges. The Elsternwick Creek enters the sea through the Elwood Swamp; there is a flattening of its gradient, but in all the Brighton valleys the reverse occurs. There is, to put it otherwise, never room for the fall to continue to the sea at the same rate as the fall from 30 to 20 above sea level. All of them must be regarded as slightly encroached upon by the sea. From Brighton Beach the coast runs in general nearly south-east, curving out to the west at points due to the greater resistance of the brown rocks. The attack of the sea is evidently more powerful here than at Brighton, as is seen also in the nature of the beach sand. At Brighton also, where the coast crosses a ridge, there is a steep rise, usually back in the tea tree scrub. At Sandringham the cliffs rise higher and direct from the beach. Towards Rickett's Point there again seems to be a less rapid advance, but here the outcrop of the resistant rocks is much more continuous. From Elwood to this point most of the best dip observations give a north-westerly strike in the brown rocks with low dips 10 degrees or less. Joints are often prominent, and in these north-westerly strike is most common, though others are also frequent.

Near Beaumaris the coast turns north-east for a mile with continuous cliffs to 70 feet high forming one side of Beaumaris Bay. At the head of the bay is seen a comparatively steep dip in the tertiaries 25 degrees south-easterly. By this the resistant rocks are carried well below water level, and a vertical cliff in the soft upper beds follows, the coast having resumed a south-easterly direction. The fold is not seen all along the north-west side of the bay. At the end, where the water appears deep and the beds do not seem to be curving, it is possibly replaced by a fault or has been crossed by the marine encroachment.

The upper beds of the tertiaries are not seen on the north-west side of the bay. The highest hill near reaches 100 feet, but its top is wind-blown sand. As the removal of the upper beds does not seem to be connected with the subaerial denudation, it was probably achieved by marine action during emergence. As usual, in a very short distance from the coast, the valley system is quite independent of the coast line.

The fold at Beaumaris Bay is no doubt a part of the structure giving rise to the Cheltenham axis, its strike passing along the east

flank of the higher ground not far from several places where the east fall is steeper than usual.

Beaumaris Bay is no doubt due to marine attack favoured by the structural character. Further to the south-east the sea has had to give place to the material brought down from the east side of the Cheltenham axis, and by the Dandenong Creek. Recent marine fossils occur at the mouth of the main drain at the head of the creek at Mordialloc just above sea level.

The relation of the rocks to the valleys.

The tertiary rocks may be divided for the present purpose into two parts—the upper, very weak sandstones, usually pale coloured, but occasionally more ferruginous and then stronger; the lower usually brown and often more clayey, with ironstone bands and some strong coarse ferruginous beds. The upper parts are highly permeable, they readily lose their iron cement in weathering; probably even the more ferruginous and stronger beds yield fairly easily to soil waters. These form the bulk of the higher cliffs, and are exposed in every railway cutting of any depth in the tertiary areas. The lower less permeable beds are seldom touched in the artificial cuttings, but probably form the floor of many of the valleys. They are seen at many points on the coast, and some of the springs can be seen to occur at their upper edge.

On a catchment consisting of the upper parts of the tertiaries, a very large proportion of the rainfall must be absorbed, and if the valleys have not reached less permeable beds, may never reappear on the land surface in the vicinity. The erosive power of the stream would be correspondingly reduced, and when, in addition, there are small catchments, low grades, and only a moderate rainfall, the streams must be very weak. When the stream reaches the less permeable lower beds it will receive additions from springs. These springs must produce a local weakening, and hence greatly increase the power to widen the valley or to cut out a channel of a branch gully on the line of a spring. A steeper slope can be seen sometimes behind a spring at the foot of a hill. This power of widening has already been referred to, and is no doubt of general application. It will evidently give increased power to the stream which first reaches the less permeable beds, that is, other things being equal, to the stream on or near the anticline. A somewhat similar effect could be produced by any stream reaching the permanent water level, but in this district the two causes are probably practically coincident.

The valleys about Cheltenham have very little power to re-open their channels if blocked by any cause. For example the swamp east of the Golf Club House at Sandringham lies at the north-west end of a hollow below the 100 ft. contour, about 50 chains long and of an area of 50 acres. The whole catchment up stream from the swamp is only about 300 acres. If a barrier below the swamp were only to reach 102 ft. above sea level, it would require, neglecting the depth below the 100 ft. contour, two feet of water over more than 50 acres to surmount the barrier, or over 4 inches of rain delivered into the hollow so rapidly that absorption could be neglected. A very low barrier is evidently insurmountable in such a case. The valley would be re-opened by the stream cutting back from the lower side of the barrier, and as the direct catchment here is very small, the chief agent would be the oozing of water along the old bed. If the old bed had reached impermeable material this would be much more powerful. A stream which has reached less permeable beds is therefore much more able to keep its channel open. Wind action or the wash from adjacent slopes might make a barrier, especially after a portion of the heath had been swept by fire and the sand left unprotected. It may be noticed that while two and a half feet to the chain can be regarded as moderately steep in the tertiaries, some hillsides reach as much as 10 feet to the chain, and might rapidly supply much material from these relatively unstable slopes.

As has been noticed, strikes of beds and of joints are often north-westerly in the tertiaries. Any actual inequalities of surface produced by slight folding before emergence of these beds would be liable to be largly or wholly levelled by marine action during the elevation. Relatively weak parts might even be excavated, and these weaker parts would probably be nearer anticlines. Hence there is no probability of the production of anticlinal ridges, but there is a strong probability of lines of easy excavation parallel to the strike of the folds. The north-west and south-east valleys therefore, besides being near the direction of steepest slope from the axis, are probably structurally in a strong position. The relation of the unusual fold at Beaumaris to the Cheltenham axis is already noticed.

Explanation of Surface Features.

The Brighton valleys from their simplicity and regularity are no doubt the only system which has ever existed on this area. They do not exactly follow the present general slope, but this may have been altered, either by a general depression to the south or, less likely, by

the process of denudation. But to form such a series of parallel valleys, so close together, merely as consequent streams, seems to require a very regular original surface. Small irregularities can scarcely be negligible with valleys so close to one another. Therefore it is probable that the valleys have been from the first guided by lines of easy erosion. Actual inequalities of surface to guide them need not here be required.

Further north, however, we begin to have evidence of a more important south-west fall of the country. The Notting Hill-Cheltenham axis itself falls to the south-west; so does the high land from East Camberwell to Malvern. The tributaries from the north are necessarily more important. Yet they have not been able to continue south-west. Either Elsternwick Creek and Gardiner's Creek are on lines of weakness which gave them an immediate advantage, or there was originally an irregularity in the south-west fall. There is actually no reason why the original elevated surface should not possess regularly arranged inequalities. Ordinarily streams have been able to do so much work that minor features have been lost, but here we are dealing with the weakest of streams. It must be remembered, however, that all these creeks had to start as weak streams in the upper beds of the tertiaries. It may have needed no more to determine the courses of Gardiner's Creek and the Elsternwick Creek than those of the Brighton valleys. It may be noticed, however, that Malvern Hill is a little higher than we would expect if the ridge is falling uniformly to the south-west, and that the correspondence between Gardiner's Creek and the Springvale valley on the opposite fall, favours the idea of an original structural character or inequality. The Elsternwick Creek system is a further development of a system like the Brighton valleys with the addition of the influence of the south-west fall as soon as the main axis is left. In Gardiner's Creek and its tributaries these characters are further developed. If the tertiaries north of Gardiner's Creek are mostly terrestrial, and those to the south mostly marine, this would involve an original slope of deposition in the terrestrial part and original streams before the emergence of the southern area, but these streams would all be in shallow valleys.

Area south of Carnegie and Murrumbeena.—If Main Creek ever continued to the south-west it must have been across this locality. The comparatively low levels of the ridges, somewhat lower than the hills near Caulfield station, and also than the high land to the south-east, at first suggest a broad valley. But the detail of the surface is not easily explained on this supposition. By examining

the course of the 150 and 140 ft. contours, it will be seen that the little creek at Murrumbeena takes the water from a long hollow with a distinct north-westerly trend. This is the lower end of valleys which head some distance to the south-east. The present outlet is a mile back from the north-west end, and is evidently well able to cut deeper. It seems to be clearly a new diversion of the waters of a valley flowing north-west. Immediately to the south of this hollow is another, also elongated in a north-westerly direction, and making the down stream end of a valley from the south-east. The present outlet is to the south-west, and again is a mile back from the north-west end. The outlet is more developed than in the other hollow, but is still narrow compared with the size of the hollow, and actually did not naturally drain it completely. Again it seems clearly a new diversion. The ridge south-west of this hollow, which is breached by the present outlet, is a well-defined ridge from the south end of Caulfield Racecourse to the higher land east of Bentleigh. Nor does the country to the south-west further on show any sufficient evidence of an old valley of Main Creek. There is indeed the southward tributary to the Elsternwick Creek, but eventually a south-westerly stream would reach places where the north-west valleys and ridges run right across its line. The idea of a south-west continuation of Main Creek would necessarily involve the supposition that some character of the rocks so strongly favoured easy excavation on the usual north-westerly lines as to make an earlier south-west fall a matter of little consequence, so that later valleys sometimes entered the old valley at an acute angle, heading up stream. Nor does the general run of the surface levels in Caulfield and Brighton favour the idea of an old valley, even if a broad one, crossing this area.

This argument evidently does not exclude the possibility of a stream somewhere near Main Creek before the emergence of the land south of Gardiner's Creek, but this would be antecedent to the development of the present topography. Such a stream may possibly have had its mouth about this locality, but it might almost equally have been anywhere else.

It remains to find an explanation of the absence of any outlet to these valleys to the north-west. They are not alone in this respect; on the same line are the flat in Caulfield Racecourse, with a poor outlet, and Paddy's Swamp. The most probable explanation seems to be a continued or renewed warping of the surface subsequent to the establishment of the present valley system.

There is no doubt that the elevation was accompanied by deformation of the surface.

The deformations and elevations would not be likely to cease suddenly. The flattening of the grades of all the Brighton valleys near Bluff-road has been referred to. This admits of two explanations: either that there is something which the valleys found it hard to cut through, or that there has been an elevation against the grade of the valleys which they have not yet been able to smooth out. The former explanation receives slight support from the occurrence of the flattest part of the Elsternwick Creek near the ferruginous rock of the "gravel" pits west of Bentleigh. On this view the complete obstruction of the valley east of the Golf Club House at Sandringham would be due to the flat grade allowing this stream, one of the weakest, to be completely obstructed by other causes. On the view that there has been a late deformation of the surface, the flattening of all these valleys, and the complete loss of level in the case just mentioned are the direct result of the deformation. But the diversion of the second valley of the Brighton system into the third is probably due to an earlier slight irregularity on the same line. Following the same line north such a warping would increase the power of the southward valley near McKinnon as compared with the north-west valleys, and would at the same time account for the blocking of the two hollows south of Carnegie, and facilitate the formation of a south outlet from the southern one.

The same explanation may be further extended to the course of Gardiner's Creek through the high land north of Malvern. Gardiner's Creek probably preceded the present elevation of the land. This receives some support from the levels of the base of the tertiaries, which is lower up stream than it is at this high land, and apparently falls much lower on the Yarra side of the high land. If we suppose that deformations, and not mere elevations and depressions took place, there is no reason to suppose that Malvern and Hawthorn were equally affected with the Yarra valley, in the depression which is known to have taken place there.

A similar explanation might extend to the steep fall south of the Dandenong-road at Armadale, and to the steep fall on the Notting Hill-Cheltenham axis near the Gippsland railway. It would then also explain why the southern divide of the Gardiner's Creek area is lower at Murrumbeena. It also introduces a cause with a general power of forming lagoons and closed hollows such as are numerous at and about Cheltenham and many other places.

Wheeler's Hill.—The north-west line of hills through Wheeler's Hill may be either a more uplifted area or a relic of earlier features. Jutson remarks (p. 492) that a fault scarp is suggested at

Wheeler's Hill, that is, to the east of the hill; but also that the hill seems to rise above the general height of the plateau in this locality. Possibly there may be a fault on the north-east of this group of hills, but the deflection produced in the Dandenong Creek may be sufficient cause for the steep slope along the north-east fall. My suggestion that there has once been a continuous ridge to beyond Surrey Hills may raise the objection that it would seem that the country about Blackburn should have had its easiest outlet to Koonung Creek, which, with a direct course, now joins the Yarra at 24 ft. above sea level. But if we imagine the low valley of Koonung Creek filled in, and the ridge from East Camberwell continuous to Doncaster, the outlet of this area is difficult by any route, and Main Creek might at some stages in the development be the easier in spite of the necessity to cut through the ridge.

Jutson (p. 479) mentions a decreasing throw of the Brushy Creek fault from north to south till it is no longer traceable as a fault, and appears to be represented by a gentle tilting on a line continuing south-westerly toward Springvale (with a possible fault for a short distance at Wheeler's Hill). Following this idea it seems better to consider this fault line as replaced by a wider easterly tilt from the Notting Hill axis. Then the course of the Dandenong Creek at Wheeler's Hill is in accordance with the direction of tilt till it finds its way through the hills. The Springvale valley also lies within the tilted area and further south the tilt extends from Beaumaris across the Carrum Swamp.

The slope on which the formation of swampy land appears at the lower parts of the creeks is in close agreement in the three examples in this district. The Dandenong Creek begins to be swampy below the 50 ft. contour, falling from 50 to 40 in 50 chains, or a grade of 1 in 330. The channel from Dingley southward falls from 50 to 30 in 65 chains, and from 30 to 10 in about 105 chains; this brings it into the once swampy land north of the main drain from the Dandenong Creek to Mordialloc. The Elsternwick Creek falls from 50 to 30 in 60 chains, and from 30 to 10 in 106 chains; thence to the outlet is much flatter.

In considering the lagoons, the question suggested itself as to whether there was any cause acting to keep them from silting up or even to increase their size. In spite of statements about running sands in some wells, there does not seem much likelihood of underground channels by which sand could move; and actually the closed hollows usually hold water. There seems a slight possibility that under peculiar circumstances some of the upper sand might slip in mass on an inclined clayey bed either down a valley

or sidewise. As the slopes which stand are sometimes about 10 degrees on the surface, it would probably want a steeper slope than this. It might possibly occur at a time of ground movements or warping or elevation, but would be exceptional. Wind action would tend rather to fill than to excavate, as the moist bottom of the hollow must be less acted on even if the wind blew up the valley. The existing closed hollows may then be regarded as mostly newly closed.

General Summary.

The detail of the drainage system is not to be regarded as developed on a simple sloping surface. A south-westerly fall is noticeable across the Gardiner's Creek, and, to a less marked degree, the Elsternwick Creek area. Slight indications of it are seen even in the Brighton district. A south-westerly and southerly fall is also seen in the Springvale area; and the parish of Mordialloc (i.e., from near Clayton to the main drain of the Dandenong Creek) is under the influence of the southerly fall to the Carrum Swamp. But the drainage system is largely controlled by the Notting Hill-Cheltenham axis, parallel to which is a subordinate axis through East Camberwell. An easterly tilt from the latter and other late warping movements are probable. But primarily the Notting Hill-Cheltenham axis divided the north-western from the south-eastern streams. The south-westerly tributaries, though important, in many cases seem to be definitely blocked at certain lines, especially that on the south-west sides of Gardiner's Creek and the Springvale Valley. This feature, combined with the extreme regularity of the Brighton system, and the structures of the rocks so far as seen, favours the idea that the streams are guided or strengthened on their south-east or north-west courses by lines of weakness or by structural features, and that there may even have been original reversals of slope against the south-west fall in some cases.

All the valleys in their earlier stages were in the weak and absorptive tertiary sandy beds. On reaching impermeable beds such a valley would receive additions from springs, and weak places would be produced on the lines of springs which might result in a great power of widening the valley or cutting a tributary valley.

Closed hollows are of frequent occurrence, and are easily produced owing to the extreme weakness of the upper parts of the streams. Small local causes may have possibly produced some, but

some of the larger ones more remote from the valley heads are probably due to warping after the development of the valleys.

There is no necessity to regard the late depression, known to have occurred in the Yarra valley, as uniformly affecting a large area, but rather as part of a movement which acted unequally in different places even a short distance apart.